

Ancient Buildings

Digital Survey and New Hypothesis.

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Abstract: The Church of Santa Reparata and the Baptistery of San Giovanni are located inside the ancient town walls of Lucca, Tuscany. They are examples of a multi-layered building, built on an *ancient Roman domus*¹ that evolved into a baptistery and a church. The first settlement church is dated to 754 A.D. and has evolved to the current configuration that now is the topic of relevant archaeological and architectural studies. The baptistery has had various functions: it probably evolved from a Roman residence in pre-Christian period and then was changed architecturally to suit the needs of the urban evolution.

The Poster presented at the Conference of Cultural Heritage and New Technologies (CHNT) 18 - 2013, focusing on the transformation of the baptistery, will focus on the first version, characterized by a central *quadriconco*² plan, debated by different research results of the construction phases.

The research work in debate was developed on the analysis of the walls and the comparison with the similar baptistery of Biella, Piemonte. The baptistery of Biella is a rare example of an existing baptistery *quadriconco*, built in the 10th century on ancient Roman ruins. San Giovanni in Lucca demonstrates a hypothetical presence of a Roman *Nymphaeum*³, which later developed into the current layout. Researchers disagree whether or not the baptistery really functioned as baptisteries in the Roman period. The use of various survey methodologies such as digital laser scanning and photogrammetry Structure from Motion (SFM), offers different methods of comparison by which to develop alternative hypothesis about the structural evolution of this monument.

The intentions of the survey are to highlight the flexibility of investigation that allows digital techniques, supported by quick and easy production of digital comparative models. These methods are an example of "correct documentation" through the intersection of cultural analytical methods of their own architecture and metric survey.

Keywords: *quadriconco* plan, digital survey, baptistery, Lucca, *Nymphaeum*

Digital survey is a new method to investigate an old hypothesis by faster and easier techniques that confirm and produce new ones. Our work is about two experiences; the first is a laser scanning survey and the

¹ In Roman Architecture it was a single home of a noble-rich family.

² A kind of central plan with four apses around it.

³ In Roman Architecture it was a fountain with a temple dedicated to Nymphs.

second is a photogrammetric survey, applied to two important urban archaeology sites in Italy. The study on the baptistery of Lucca with the sample in Biella gave interesting results about its origin and some considerations about two different workflows for cost, methodology and instrumentation.

General View

Historical Background about Christianity and Baptisteries

Christianity is a monotheistic religion that began as a Jewish sect in the 1st century and spreads from the Middle East to Asia Minor, Egypt, Roman Empire and Europe. This new religion was opposed by the Roman Empire for a long period; persecutions ended in 313 A.D. with the Edict of Toleration by Constantine I and Christianity finally became the State Church of the Roman Empire in the 380 A.D. with Emperor Theodosius. Baptism was one of the sacraments to initiate a passage into the Christian religion. As the period of persecution was long and hard, the first Christians hid during their rites and liturgies. Before they began to build churches, they practiced in catacombs, thermal buildings and the *Nymphaeum* of Roman homes where they used running water for baptism.

The word baptism comes from the Greek "βάπτισμα" which means "immerse". In ancient times, adults received the sacrament carried out by immersion in water in a river or in a bathtub with running water. Later baptism developed other methods of liturgical rites and today the *Latin* and the *Ambrosian* are the only two rites practiced. The two rites differ because in the *Latin* rite water is poured over the child through a shell, in the *Ambrosian* method the head of the candidate is completely immersed in the water source.

Later in the history of Christianity, churches and consequently baptisteries were built on Roman soil that was present in almost all important Italian and foreign cities. Consequently the baptismal font was very often placed at the location of a thermal bath, usually among the public buildings and the most prestigious residences.

After the confirmation of Christianity as the State Church, when the clergy started to build churches to practice their religion, they also started to think of the architecture of the baptistery. Initially baptisteries were a separate entity, so that the new practitioners would avoid going into the church before receiving the sacrament. The two buildings remained, however, functionally linked. Sometimes they were structurally connected by interior corridors (such as an extension of the transept). Other times they were connected through the arcades, and finally as free standing units. They were always built very close to the apse, beside or in front of the main entrance of the church. Today, baptisteries are not always a separate building, but they are almost always found inside a dedicated chapel and are equipped with a baptismal font, located near the entrance of the church. This case study can be considered an example of a baptistery built on a pre-existing Roman substrate, with some structures, as walls, pipes and bathtubs placed or transformed to a similar function.

Geographical and Historical Background about Lucca and Biella

The city of Lucca is located in the northern part of Tuscany, Italy. It has a large, well-preserved cultural heritage. The city's origins are still questioned by researchers: some think that the city was founded by the Ligurians, others think it dates back to the Etruscans. What is certain is that in 180 B.C. it became a Roman

colony. This is evidenced by its beautiful, urban square organized by the *Cardo* and the *Decumanus* street, the forum (San Michele Square), and the first city walls dating back to 56 B.C. With the advent of Christianity the first places of worship were Roman churches and baptisteries built on the ruins of noble houses and Roman bath houses. The presence of large bathtubs allowed an adult to be fully immersed for baptism. For this reason several hypothetical reconstructions were undertaken to see how the Christian church developed from a pagan building like an ancient *domus*.

The city of Lucca, fed by the river Serchio and covered by rich underground water, has always been able to count on a large quantity of fresh water that is available for public use. It is plausible to think that the city and the major *domi* could be supplied by the underground thermal springs.

By comparing the story with historical and archaeological remains below the current complex of San Giovanni and Santa Reparata, one can conclude that it arises from an underlying Roman forum reworked over and over again until its current layout. This type of hypothesis is in conflict with that of other archaeologists, believing that the current building built on an old *quadriconco* baptistery is similar to the very newer baptistery of Biella and those of other Northern Italian cities.

The *quadriconco* structure of these Romanesque Baptisteries came into use in Italy about 4-5 centuries after that of Lucca. In the African colonies it was already used in this period, so archaeologists think this may be the result of the immigration to Italy by African Catholics due to the Barbarian invasions.

For this reason we decided to compare the structure of Lucca with the one in Biella, which also presents a Roman matrix. Through diverse surveying strategies a more factual result can be documented and structural considerations for the hypothesis of "New baptistery on Old baptistery" would lose credibility.

The city of Biella, located in Piemonte a region of Northern Italy, has very ancient origins. Its archaeological excavations in the 1950s and 1960s have unearthed materials dating back to the Iron Age (12th century B.C.). Therefore, there are many traces of the colonization of the territory of Biella by the Celts long before the advent of the Romans, such as tombs discovered with the excavations in the historical center. The presence of a Roman matrix, suggests that most of the monuments erected later may have had their foundation on a pre-existing and well-established Roman base, which has partially been able to influence the shapes of the new buildings.

In this case study the baptistery of Biella is a particularly interesting example of Romanesque, located right next to the cathedral dating back to the 9th-10th century A.D.

The Roman Lucca and the Excavation under the Church of Santa Reparata

Lucca evolved around the area of the Roman Forum that contained the main public, civil and religious buildings. In the first century A.D. a dense network of aristocratic homes became part of the urban tissue of the city. In the 2nd-3rd centuries A.D. the direct consequence of the crisis of the forum can be found in the downsizing of the *domūs* and the progressive deterioration of the central area in favour of the South-East portion of the city where the Cathedral was built in the 4th century A.D.

The archaeological excavations in the territory of Lucca were numerous, both in ancient times, and recently. From 1974 until 2005, the old town with all its points of interest (the major churches and squares, the oldest roads, etc.), have been meticulously examined to help the reconstruction of the history of the city.

The excavations of Santa Reparata and San Giovanni have delivered most significant findings in the apse, the transept, and the baptistery.

The structures that we see today underground, date mainly to two phases:

- The Roman period, from the 2nd century B.C. to the 1st century A.D.;
- The early Christian period, between the 1st-2nd century A.D., which includes most of the structures (fig.01).

The first level presents several fragments of earthenware flooring. In the Baptistery at a depth of -3.35 m, one observes a reddish colour with mosaic decorations of the Republican period (4th-5th century B.C.). In the transept flooring a particular pattern was found at a depth of -3.18 m, together with a stone wall structure and a connected marble pipe.

At the second level (fig. 1) two parallel walls [A and B], 0.40m high, with ranging thicknesses of 0.55 m to 0.30 m remain at the same distance (1.5 m) even after a discontinuation of the baptismal font. This could be identified as a corridor at a depth of -3.10 m depth. A floor of *sesquipedali*⁴ bricks at a depth of -2.66 m [C] is connected to the septum wall [B] through a row of bricks inclined at 45 degrees with respect to the plan. A section of conduct in brick recycling [D] was discovered on the western side of the Baptistery, which was to merge into a circular well for waste water.

Giving an unambiguous interpretation of these findings is very difficult, due to two factors that have negatively affected the survey and, in general, the study: the presence of an aquifer, remediated by removing water with a sump pump, and the loss of the previous stratigraphy of the Church of Santa Reparata. However, some conclusions can be summarized as follows: the remnants from excavations, surely the oldest ones, are to be attributed to a noble *domus* (serving as a *peristilium*⁵ or an *impluvium*⁶), which was an integral part of the urban tissue of that time. It is more complex to comprehend findings of later times, which on one hand could be attributed to a larger *domus*, but on the other hand, to a thermal building. If one takes into account this assumption, the stratification of the findings of a later period may be more understandable.

To trace the origins of the baptistery, the church adjacent to it is investigated. Historians and archaeologists are in agreement to its location. It is oriented in East-West position and perfectly parallel to roads. Given its significant size, it would date back to a climate of peace definitely marked in 391 A.D. as a result both of the Edict of Constantine to that of Theodosius, Roman Period.

Lucca - Three Hypothesos on One Structure

Numerous assumptions were made by scholars regarding the construction of the first baptistery, sometimes in comparison with other typical buildings and also from the comparison between buildings and the historical events of the period (fig. 2).

⁴ In Roman architecture, bricks had dimensions of 1,5x1,5 feet or 1,5x1 feet.

⁵ The arcades courtyard of the Roman domus.

⁶ In the Roman domus, a water tank in the centre of the impluvium, used to collect rainwater

The first finding to be evaluated is certainly a cobbled herringbone wall that ideally continues from the basilica along and beyond the west wall of the transept for a total length of about 50 late antiquity feet (*quadratum populi*⁷). However, when trying to draw a square with this form, it is noted that the circular tank is decentralized, and therefore two hypothesis, can be considered: the first that this was a pre-existing body of an earlier baptismal font of which no trace remains, or the second that the tank was a pre-existing primitive thermal spring or *Nympheum* of an ancient *domus*.

The study of this wall has been addressed by Guglielmo de Angelis d'Ossat who formed the first hypothesis of the reconstruction of the Baptistery. According to him there was a clear intention to complete the early Christian Episcopal building with a square-shape and equal height, which would have functioned as the baptistery. Because of its magnificence and the barbarian invasions, the work was left incomplete. This hypothesis of reconstruction, valid from the historical point of view ignores two facts: the existence of a primitive baptismal plant installed on earlier Roman structures, and the size of the building, which is too impressive compared to other examples of architecture in the baptismal period.

A second hypothesis of reconstruction has been developed by Guglielmo d'Ossat and Giovanni De Marinis, namely that it was impossible to complete the colossal square planned Baptistery. So a more modest project developed a *quadriconco* baptistery, inside the initial quadrant. It consisted of a central square with four semicircular apses. One of the four concave apses, however, differs from the others by its particular shape. According to researchers, this was the niche opposite the altar, and it had to include a larger number of worshippers. Therefore it was modified to a rectangle with rounded corners, without sidewalls such as those found in the remaining niches. Historians speak thus of an ideal three-apse matrix.

In this case also the elevations do not support the validity of the hypothesis, but one can make some historical comparison with other types of baptisteries of the same period.

The type *quadriconco* was not very much used in Italy until the middle of the Romanesque period (9th century A.D.). Its origins, according to the two scholars, could derive from Africa. Examples are found in Tigziert, Tebessa, and elsewhere: the landing of the Vandals of Genseric in 429 A.D. in North Africa created situations of great distress that forced bishops and priests to take refuge in Spain, Sardinia and the Tuscan Archipelago, reaching also Lucca. The facts that differ from this interpretation are related to the workmanship. Rustic masonry, seen in stone and in remnants, and a thickness not always consistent, does not allow one to ascertain which type of metric unit (whether Roman or early period) had been used for the structure.

The third hypothesis of historical reconstruction, has been developed by Giulio Ciampoltrini on the basis of the stratification of the structures documented during the first excavations in the baptistery (1885). He speculates that the shape of the *quadriconco* walls, resulting from the adaptation of a building of the Imperial Age (2nd century A.D.), creates a plan with a square apse on the north side towards the coaxial entrance doors, which has been subsequently added on the side apses (5th-6th century A.D.). The evidence in favor of this reconstitution can be found in several situations: building techniques, flooring and the duct-work.

⁷ In pre-Christian Architecture, the space of the Cathedral for the worshippers.

The first point is that the structures found in the apse of the Church (2nd century A.D.) together with those of the central body with a square base, have been built with techniques more refined than the apses of *quadriconco*, which are instead irregular foundations with a heterogeneous mixture of stone, bricks and poor mortar. The walls of the square body along with those of the apse are far more homogeneous than the apses that are huddled up. In the body of the square different types of flooring exist: a cement floor of an *opus sectile*⁸ from the Imperial Age, fragments of polychrome marble with white mortar and other bits of *bardiglio*⁹ marble. The depth (-2.44 m) of these findings coincides with the findings of the Church of Santa Reparata and the neighboring Palazzo Bernardi; showing the great work of urban reorganization at the time. Finally the most important consideration must be made on the discovery of a section of brick duct which directs the water flow from North to South. At the floor level above, the original baptismal font, discovered at -2.81 m, suggests that in ancient times the building housed a fountain with circular base.

In the light of these data, Ciampoltrini assumed that the first baptistery arose from an environment with a square having thermal functions. In fact, it was common for the *domūs* to be the first seat of worship and for this reason they were often created inside the baptistery of thermal springs.

Ultimately, the building has undergone many changes over time, for instance: the apses expanded in space to give sacredness to the environment. This is seen in the different construction techniques used suggesting many evolutions with ever increasing size.

Biella - A Comparison

The Baptistery of Biella is an old building built and later expanded on the ruins of a pre-existing pagan burial site. It is dated to the late 9th century A.D. The Baptistery has a distinctly Romanesque structure (in accordance with the Christian tradition), built of local stones mixed with pieces of brick, a quadrangular base, with a semicircular apse on each side, separated by the four corner pillars that support the octagonal lantern. Below the ground level there is a Greek cross crypt carved in 1791. The structure is surmounted by a slender lantern decorated with mullioned windows on all four sides. The lantern is instead characterized by lancet windows present on each face of the octagonal prism. Each apse is decorated with three lancet windows, except the front, where the central lancet window is replaced by the door. This door is famous for its late Roman bass-relief carved in marble: it was most likely recovered from the underlying Roman tombs and has led a large number of historians to believe that the entire structure was adapted from a pagan building.

Structurally, the Baptistery of Biella (fig. 3), in accordance with similar buildings in the cities of Mariano Comense or Galliano, presents a very important angular junction between the lobes and the central square of the body, just to hold the weight of the vaults with a span of 10,00 m to cover. This is not the case in Lucca, where the walls are not square and the semi-circular walls have been built just near them, not linked.

⁸ Roman flooring with stone cut in geometrical figures

⁹ A kind of marble typical of the Apuan Alps

So it's hard to think that this kind of solution could support the weight of vaults for a span of 16.00 m, really higher than in Biella.

Two Different Survey Campaigns: Our Findings

The analysis of the two cases starts from two different survey campaigns implementing a real experience on the research of new hypothesis for buildings of historical value. This is achieved with specific hardware and software tools. Digital survey is the base of our research, because with automated instruments, one can create a fast and accurate workflow in terms of models and reconstitution useful for theoretical investigation and bibliographic research.

In Lucca we used an existing 3D laser-scanner survey, performed in April 2006 by Giorgio Verdiani and Sergio di Tondo (fig. 4). After the registration of the pointcloud, we derived images of sections and plans (snapshots), created architectural drawings to meet the needs of our research (horizontal plan of the Late-Roman and Late Middle-Ages). These images are instruments for analysis of existing geometries. They have been re-processed with CAD applications to reach more rationalized geometries which are useful for the comprehension of the structural phases identified during the past excavations. We can say that this type of survey technique is very accurate and fast. Also the restitution of the data and its re-processing is quick. Some criticism could be made about the necessity to take too much time to perform the survey and about the cost of the project. The instruments are very expensive and the survey campaign needs an entire team. The entire process of restitution has been made with a computer of professional quality resulting more than suitable results for the needs without creating any instrumental limits to the process.

A photogrammetric survey technique was used for Biella with the desire to make the campaign simpler and quicker. The surveying of the inside and the outside has been made only with the pictures. A point cloud was produced and converted into a mesh and texturized using Agisoft Photoscan (fig. 5) and Maxon Cinema 4D to reach the final three-dimensional model useful to observe and to extrapolate plans and sections.

The final 3D model is constituted by a triangular polygons mesh defined by a cloud of 3.4 million points. The model is obtained by two calculation processes: the first for the generation of the outer surface is derived from a single survey, developed with photographs taken from the ground and from above; the second partial mesh for the inside, has adopted a dual organization of survey: it evaluated the results of the two digital building photogrammetric survey and we chose the more usable.

The survey of the exterior is characterized by a total of 164 images: 111 poses were taken from the ground floor with a medium average distance from the subject; 53 at two higher altitudes, depending on the accessibility of the surrounding buildings.

The processing of the data has developed through several attempts of calculation progressively decreasing the process quality. The first step of computation, the alignment of the individual images for the construction of the point cloud, was developed with demands for accurate calculation and did not produce any problems. The subsequent construction of the mesh was hindered by hardware limits, subjecting the calculation to alternative combinations of parameters in order to obtain a usable result with a good level of detail.

Therefore when evaluating the acceptability of the results, a small test has been developed on software revealing that the high detail of the construction of the poly-surface associated with high values of reduction

in the number of faces does not produce a model small enough to be handled by external programs. Only a calculation of the average accuracy associated with lower reductions values led us to the construction of the exterior model of the building.

The partial mesh is defined by approximately 2 million points with an average quality of polygons.

For the interior survey two methods were chosen: the first method consists in taking photos along the entire perimeter of the masonry, obtaining 284 images and a redundant coverage of the subject. The second method consisted of taking photos from the four sides of the plan, covering the space completely with a total of 67 shots. The processing of the data was easier with the second survey method. The large number of images of the first survey produced a point cloud too dense and unusable with our graphic hardware. The partial final model was selected among several attempts to construct the mesh. Like for the exterior, a medium software associated with a reduction of the faces contained in the data provided a more satisfactory model.

The two meshes obtained were aligned by means of a manual survey of the access openings. The model was used for the comparison with the plan in the Baptistery of Lucca. Subsequently to this, the mappings were calculated for the model as to render the image by completing the entire survey of the Baptistery of Biella with digital photogrammetric procedure.

The positive points are that the execution of the survey campaign can be performed economically, quickly and by a single operator. The negative points are the length of time Photoscan requires to reach the final results. This result concerns the instrumental limits, even if the useful data carrying out our research were comprehensive and at an equivalent level of the data obtained with the first technique.

Finally both techniques have responded to the questions posed at the beginning of the study: the desire to achieve the accurate levels of laser scanner techniques with photogrammetry have been partially achieved, excluding the hardware limit, offset by its speed. From the evaluation made by researchers who analysed findings and stratigraphy before, three assumptions were examined: the most reliable was a comparison with the baptistery of Biella, similar in plan, but not in historical period (10th- 12th century A.D.). The laser scanning survey required three days of scans, a laser scanner Leica HDS 2500 which acquired 60,000,000 points with an accuracy of 6 mm. The photogrammetric survey of Biella took two days, taking pictures outside and inside the Baptistery. An SLR Canon EOS 5D camera was used for a total of 542 pictures. It was observed that the first hypothesis does not seem reliable for historical and structural reasons, because the walls measured 50 feet and there is no evidence of this or of its repetition for a quadrangular structure. This structural situation presents at least two historical oddities: the first is that the wall seems to be a continuation to the church, as if the two buildings were already connected and the tub is not centered, therefore creating an impossibility of a zenithal oculum vault (fig. 6). The second hypothesis is probably wrong because the *quadriconco* structures were still not in use in Italy, the thickness of the walls are really too thin for the length to be supported and the quality of the mason work is modest, such as the nodes of the body square, the buttresses, and side apses all lacking any anchoring.

Conclusions

Unlike the first two hypotheses, the third hypothesis seems correct. Ciampoltrini analysed the Baptistery first from the quadrangular central body, which is perfectly aligned with the baptismal font. Therefore it is possible that a central zenithal oculum existed. The masonry proves to be solid and well structured, dating from the 2nd century A.D., with straight corners and balanced. On the north side of the square body traces of a small apse have been found. It is therefore possible that this first square body with single-apse and a door opposite to the niche, certainly derives from a *domus*, although the side niches have been added giving a much larger sanctity to the building. For this reason, the apses seem to be only near to the building and not linked to. The thickness and the quality of construction are thus not the best: the apses were adorned but not structurally altered, supporting only their own weight.

These conclusions are based on an updated survey campaign evaluated from past results, a structural comparison with other similar and contemporary buildings in Italy and in Africa, with the Baptistery of Biella being one of the most important. As a matter of fact, the digital survey campaign gives more accurate, totally usable and three-dimensional data that can be studied in depth and with reduced error margins respect with to the classical survey methods.

The findings disprove the first two existing hypothesis in favour of the third by Giulio Ciampoltrini, not only through a more in depth morphological comparison, but also for the structural observations made by architects on this study.

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Pictures

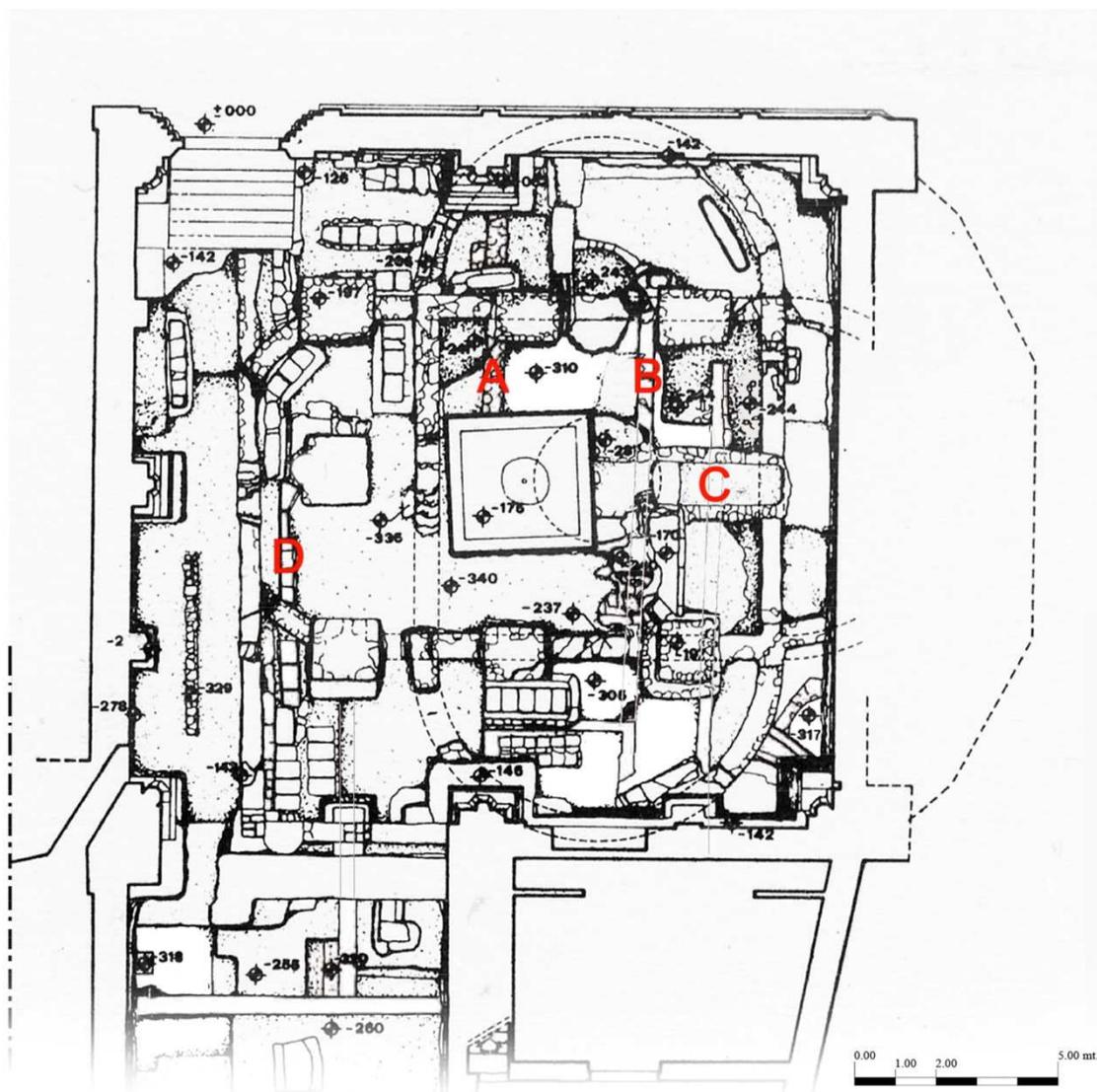


Fig. 1 – Baptistery of Lucca – stratigraphy plant (Copyright: Elena Bartoletti, Angela Mancuso, Andrea Pasquali)

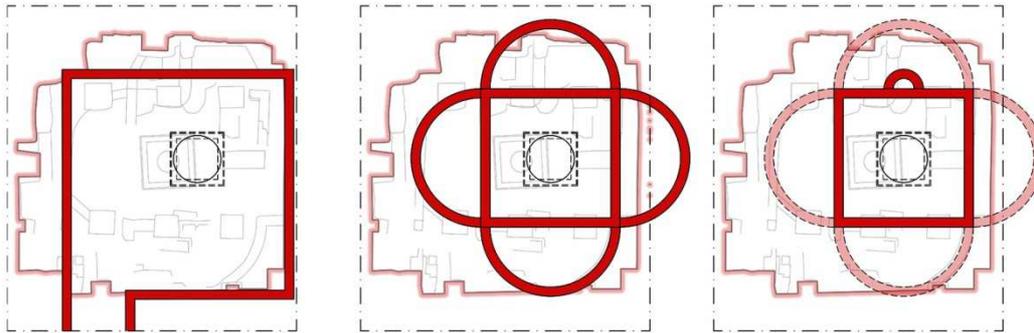


Fig. 2 – Baptistery of Lucca – hypothesis of the construction phases (Copyright: Angela Mancuso, Andrea Pasquali)



Fig. 3 – Baptistery of Biella – main front - (Copyright: Angela Mancuso, Andrea Pasquali)



Fig. 4 – Baptistery of Lucca – pictures during survey campaign (Copyright: Giorgio Verdiani)



Fig. 5 – Baptistery of Biella – picture and point cloud (Copyright: Angela Mancuso, Andrea Pasquali)

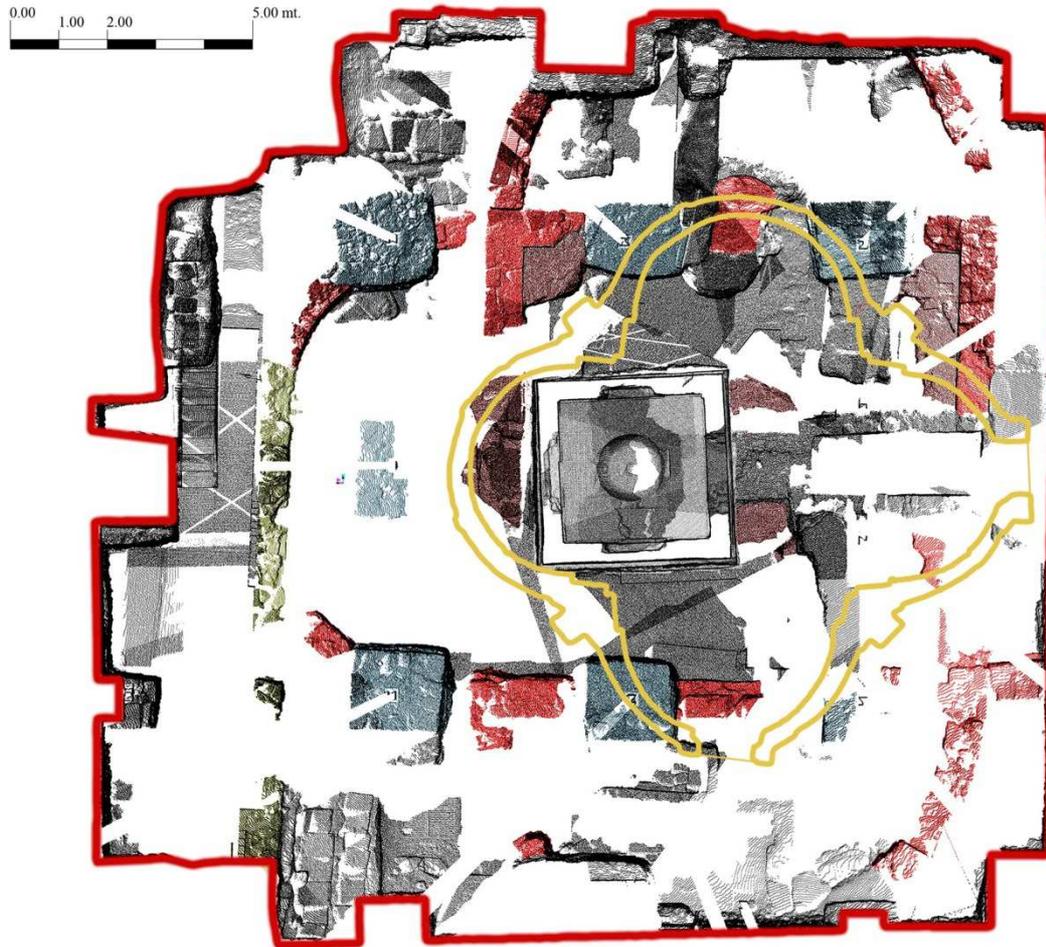


Fig. 6 – Baptistery of Lucca – Comparison with Baptistery of Biella and stratigraphy color suggest– plant (Copyright: Angela Mancuso, Andrea Pasquali)

Imprint:

Proceedings of the 18th International Conference on Cultural Heritage and New Technologies 2013 (CHNT 18, 2013)

Vienna 2014

<http://www.chnt.at/proceedings-chnt-18/>

ISBN 978-3-200-03676-5

Editor/Publisher: Museen der Stadt Wien – Stadtarchäologie

Editorial Team: Wolfgang Börner, Susanne Uhlirz

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